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ABSTRACT

The growth model of intelligence; i.e. intelligence is the product of genetics plus environment (I.Q.=G+E), is discussed and questioned. If the growth model is discarded, formulating the problem of the development of intelligence in different ways and thinking of different possible technologies for changing intelligence can begin. The child constructs his own environment. He interprets the environment, and it is the environment as interpreted that makes up the psychological environment of that child. Development is not a unidimensional, monotonic process of growth. The growth model takes no account of cultural diversity. The model presented here for psychological development is based on the phenomenon of differentiation. Development is directional rather than incremental. This model illumines the problems of compensatory education. (Author/LBB)

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STUDIES IN THE LEARNING SCIENCES 4

PATHWAYS IN DEVELOPMENT

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STUDIES IN THE LEARNING SCIENCES 4

PATHWAYS IN DEVELOPMENT

by

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
1977

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Studies in the Learning Sciences is a series of major papers by scientists participating in the International Learning Sciences Programme (CERI - OECD) on the research questions with which this programme is mainly concerned, in its efforts to reformulate the problems of ability and demand for learning :

1. Cognitive effects of scholarisation
2. Literacy and its pre-history
3. Informal learning and memory
4. Inter-generational strategy
5. Early human development and its consequences
6. Theoretical models of behaviour development
7. The design of experiments and design of learning situations.

The papers are published simultaneously in English and French in order to bring productive thinking in the learning sciences to the attention of a larger public.

The research we do on development and the technologies we use to try and change the developmental process, hopefully for the better, all depend on a general underlying theory, of which there are, at any time, competing specific versions. There is one such underlying theory at work today, a theory which is rarely if ever explicitly stated and a theory which I think is completely wrong. I shall try in this paper to present an outline of this theory, which informs most of the present-day psychological research. I shall try to point out in what ways I think it is inadequate and perhaps old-fashioned, and then go on to suggest a different abstract model for the developmental process along with some possible technological applications of that different model.

The basic model of development that underpins theorising by authors as diverse as Bijou (1975) and Erikson (1950), the model of development that is implicit in most of the research that is published today and which was responsible for most of the attempts at compensatory education seen in the last few years, is a model derived from studies of the growth process. The process of physical growth is a relatively continuous, obviously incremental process. A child at five is bigger than the same child at four. If we have a child aged eleven and five foot tall, it is obvious he is the same child as he was at ten and, say, four and a half feet tall. As a child gets older he gets bigger and as he gets bigger he comprises everything that he was before plus some additional increment. The description of growth is therefore relatively simple; comprehending the process is also relatively simple.

The height that a given individual will attain is a function of his genetic endowment and his nutritional opportunities. The better fed any given individual is, the taller he will be, up to some limit beyond which he will simply become fatter. The same individual fed just enough to survive will reach a lesser height. However, height basically seems to be determined genetically, with input from the environment in the form of nutrition determining at what point on the reaction range of the genotype the individual will terminate as phenotype. The individual with a given genotype might be anywhere between 5'9" and 6'3". Where he finishes up within that reaction range will depend on the quality of nutrition available to him.

Figure 1 shows the range for height in Japanese children in three nutritional environments. The shortest children were those who grew up during and immediately after the war in Japan when food was at a premium; the intermediate groups were those raised in a prosperous Japan; the tallest group are Japanese children raised in the United States, which has the highest quality of nutrition. Although

presumably the gene pool for all three groups is the same, the terminal height is different and seems to correlate perfectly with the adequacy of the nutritional input. Note that the differences between the three groups can be expressed in terms of a single dimension - height, a dimension which is continuous and obviously permits only a quantitative variation.

A comparison of Japanese, Japanese/Americans and Americans all living in the State of California allows one to estimate the proportion of variance contributed by genetic factors alone. Figure 2 shows that this is also quite large. In the case of height, then, one can study nutritional variables and genetic variables relatively independently. One is measuring a simple quantitative dimension and can thus obtain very simple explanations for individual variations in height. The genotype of the individual and his nutritional circumstances interact in a very simple fashion so we can say that height is a function of genotype and environmental input, a very simple additive model which is perfectly adequate to account for the data currently in existence on pure physical growth.

Many psychologists view behavioural development, the development of psychological function, as something which is analogous or homologous, to the process of growth. Writers such as Jensen (1969) and Wohlwill (1973) explicitly compare psychological development with physical growth, seemingly implying that the functions that describe the one will do to describe the other. Throughout his excellent book on the concept of development Wohlwill frequently refers us back to the process of physical growth as a model for psychological growth.

I think the model of physical growth must have been in the back of Binet's mind when he constructed the I.Q. test many years ago. These tests, remember, were constructed on the assumption that the seven year old child is more intelligent than the six year old child who is more intelligent than the five year old child and so on. In all cases there is the assumption that a seven year old, for example, can do everything the six year old can do, plus something. This assumption is used to define the concept of mental age, which by definition grows with chronological age, and chronological age of course grows continuously. It is no wonder then, that intelligence is seen by intelligence testers as a unitary dimension continuously increasing with age. The assumptions that underlay construction of the first and all subsequent intelligence tests made such an outcome necessary. Intelligence on this model is a uni-dimensional measure like height. Thus, the intelligence of the nine year old is seen as the intelligence of the eight year old plus whatever changes are wrought by that extra year's growth in the world. The analogy between growth in intelligence and physical growth is thus clear.

It is no wonder that writers who accept the analogy for growth

of intelligence should come up with analogous explanations of the developmental process underlying changes in intelligence. Intelligence, according to the growth model, or the implicit growth model, is a joint function of genotype and environment. The relation as stated by Jensen, and not seriously challenged by anyone save Watson, is that I.Q. equals G plus E and that there is an additive relationship between G (genetic factors) and E (environmental affordances) in the genesis of a particular intelligence level. The amount of variation assigned to G on Jensen's model is rather large. On other models it is rather lower but on no model that I know of is it less than 50 per cent. The relationship is typically held to be additive with few people arguing for more complex forms of interaction.

The role of the environment in the generation of intelligence is not as simple as it is in the case of physical growth, however. Most people seem to assume that the role of the environment is to stimulate the organism along the path to maturity. Somehow gene expression plus stimulation from the environment will push the developing child along a single uni-dimensional path towards development of a mature adult intelligence. This, the model of intelligence that we are all familiar with, is supposedly derived from correlational studies of inheritance of intelligence. In fact I feel it is the only sort of model we could have come up with, given the growth model of development that seems to underlie the development of I.Q. tests and similar models.

On this model the genes sum together with effects from the environment to produce a terminal I.Q. Since manipulation of the genes is beyond our reach, psychologists have been restricted to attempting to manipulate the environment of individuals in an attempt to manipulate their terminal intelligence. Since genes and environment add together it has been thought that making the environment more and more and more stimulating would result in ever-increasing increments in intelligence. There has been some disagreement over what constitutes a stimulating environment, but not any really serious discussion of it. Schoolrooms are still characterised in terms of number of pictures, number of books, number of adults ready to stimulate the child and so on. If intelligence indeed is the sum of environmental and genetic factors, and we do indeed want to change I.Q., then all we can do is manipulate the environment of the individual to make it more stimulating in the hope that we can push that individual further along the dimension of intelligence.

The most thoroughgoing test of the G plus E model of intelligence was given by the programmes of compensatory education which began in the United States in the 1960s, the most famous of which was Project Headstart. The results of these programmes, to put it mildly, were very, very discouraging indeed. Many children showed no gains in I.Q.; some showed transitory gains, and there were occasional reports of

depression of I.Q. as a consequence of the special stimulation. The reaction of developmental psychologists to this seeming failure varied according to the personal theoretical and ideological dispositions of the commentator. Jensen attracted a great deal of notoriety for himself by arguing that these results showed that, in the I.Q. equals G plus E equation, G must be worth considerably more than E, and that only by a programme of eugenics and selective breeding could we ever hope to raise the intelligence of the population as a whole. He believes that G is so much more important than E that no amount of manipulation of E can possibly be effective. Still others have responded by criticising the programmes themselves, saying either that stimulation was not begun early enough, or it was not intensive enough, or it did not go on long enough to produce the desired kinds of effects. The latter group is not questioning the basic equation that I.Q. equals G plus E; it is simply saying that E is important and, if enough stimulation is given at the right time, then G will become relatively unimportant.

The best evidence in favour of this latter point of view comes from the as yet unpublished study of Heber and his associates (1972). The aim of this was to see whether intellectual deficiency could be prevented or reduced by intervening early and continuously in the life of disadvantaged children. His subjects were black ghetto children, all of whose mothers had I.Q.s of 72 or less. The children were given intensive stimulation daily from the age of about three months. Their language skills, psychological skills ans social skills were all intensively practised. In the last report I saw the children were five years old and their average I.Q. was 125, distinctly in the superior range and very far from what one would have predicted from the I.Q. of the mothers. All through their development these experimental children had gained much more rapidly than one would ever have expected. They began to speak around twelve months of age, had normal sized vocabularies by two and had mastered some grammar by about two and a half. A control group of children, who were given the same regimen of testing but not of training, lagged behind in every one of these measures, with a terminal I.Q. of 95, higher than would have been expected on the basis of their mothers' I.Q., but obviously much lower than that of the experimental children.

This whole project has been critised by many individuals, particularly because the children are given training in the kinds of items that appear in intelligence tests. It is argued that Heber is training children to do well on I.Q. tests, which is very different from actually increasing their basic intelligence. This gets into the knotty problem of whether intelligence is what the intelligence tests test, a problem that I wish to ignore.

Environmentally-oriented theorists interpret Heber's results as

a triumphant justification for the idea that it is possible to stimulate a child along the road to high intelligence by intervening in his external environment. The study itself does not seemingly challenge the G plus E model of development of intelligence. Indeed the G plus E model of intelligence is the basis of an ingenious criticism of studies of Heber's (or indeed of the whole concept of compensatory education) which has recently been offered by Herrnstein (1971). Herrnstein argues that if I.Q. equals G plus E and if the I.Q. of genetically disadvantaged children can therefore be boosted by giving them a stimulating environment, it will be possible to boost the I.Q.s of genetically advantaged children by giving them a stimulating environment. Since the individual I.Q. is meaningless, with an individual's I.Q. only important in relation to that of all others in his age group, it follows that the genetically disadvantaged are still going to come out at the bottom of the pile, because, as Herrnstein points out, those in a position to give their children a stimulating environment will certainly do so, particularly if the government is giving a stimulating environment to those who are genetically disadvantaged. The net result will be no change in the relative distributions of I.Q.s in the population; an argument which implies that it is pointless and indeed foolish to attempt programmes of compensatory education.

While this criticism seems to depend on rather an odd view of intelligence, and on an odd view of our aims in trying to boost intelligence, it nonetheless is a criticism that follows perfectly naturally from the G plus E model of intelligence. In any event it seems to me that if one does accept the G plus E model, then Heber's study, while not suspect, is certainly impractical. It is argued that Heber's study has been successful where others have been unsuccessful because his began very early in infancy and carried on continuously with a programme of supervision and stimulation offered by professional personnel. The cost of such an exercise would forbid it being offered to that proportion of the population who most need it - a very large proportion of our population, 25 per cent at least.

As I indicated at the beginning, it is time to question the growth model of intelligence. The growth model of intelligence either implies that intelligence is genetically determined or that massive and continuous stimulation from birth is necessary if intelligence is to reach its genetic potential. Both of these are pessimistic and socially useless conclusions. Is there any necessity for us to come to these conclusions ? The only necessity, as I hope I have made clear, lies in our implicit acceptance of a growth model for intelligence. If we discard the growth model, as I believe we must, then we can begin to formulate the problem of the development of intelligence in different ways and begin to think of different possible technologies for changing intelligence.

It seems to me that the data on compensatory education itself offer a criticism of the growth model of intelligence. Heber's study is said to be successful because it began early. There is nothing in the equation I.Q. equals G plus E that shows why input from the environment should be more useful at an early age than at a later age. The growth model assumes that as a child becomes older he becomes more intelligent in the same way as he becomes bigger. I think enough data have been gathered over the last fifty years to allow us simply to throw out that assumption. It is just not true to say that intelligence develops in this simple, progressive, cumulative way.

The most important corpus of evidence on this point is that provided by Piaget and his co-workers. Piaget (1953) has argued that development should be seen as a succession of stagelike advances. However, each higher stage is seen as comprising an integration of all that was known or was possible at the lower level into the higher levels. Stage three is simply stage two plus something. While development is not seen as continuous but rather a series of jumps, there is no major conflict between a stage theory presented in this way and the growth model for the development of intelligence. I do not agree with Piaget's view of stage, as expressed above, on considering the data he and his co-workers have gathered over the last fifty years. I believe that what they have shown is rather that, as the child advances from one stage to another, he not only obviously gains in competence (which is the aspect we have most focussed on), but also in fact may lose certain competences as well. What happens when the child advances through the stages described by Piaget is that the child successively re-organises the way he views the world, the way he interprets the data coming in from the world around him. He positively changes his own psychological environment by changing the way he interprets the world around him. These changes cannot be construed as in any way incremental. They are complete qualitative alterations of viewpoint.

Note that I am here saying that the child constructs his own environment. It seems to me that on a Piagetian position it is nonsense to talk of the environment stimulating the child. A child interprets the environment and it is the environment as interpreted that makes up the psychological environment of that child. As I said above most attention has been paid to the increments in functioning that Piaget has described. However it is perfectly plain that along with these increments in functioning go general declines in capacity as well, or if not declines, precipitous drops. This sort of process is particularly clear during infancy as part of the processes of sensory-motor development.

Consider one component of the development of the concept of causality : A child has to learn that cause and effect are spatially

contiguous. The incremental side of this problem is laid out in Figures 3a and b. A child of seven or eight months, shown a desirable toy that is out of reach but lying on a cloth which is within reach, will pull the cloth to get at the toy (Fig. 3a). If the toy is not lying on the cloth, the child will still pull the cloth and look disappointed at not getting the toy (Fig. 3b). The child apparently does not comprehend the relationship between the relative spatial positions of the two objects and his success or failure in getting the toy. A nine or ten month old child, by contrast, will not make this mistake. Unless the two objects are in a particular spatial relationship, he will make no attempt to retrieve the toy by pulling the cloth. This obviously represents an advance in understanding. It also represents a profound change in the way that the child interprets events in his environment, a change that can be shown to have detrimental effects as well.

These detrimental effects are most clearly brought out in standard simple conditioning situations. Consider the situation shown in Figure 4. There, if a baby interrupts a light beam, he will make a projector go on for a fraction of a second, allowing him to look at a mobile. This event is interesting and reinforcing for young babies of three, four, five, six months. Note that in this event there is no contiguous spatial relationship between the cause and its effects. The cause is a foot movement. The effect is some feet away from the foot. We adults can understand that there is in fact a causal relationship between them because we can understand the operation of photocells. However such comprehension is well beyond that of a baby or a young child. Now, what happens when a baby grasps the idea that causes and effects are normally contiguous and that, for a causal act to have its desired effects, it must be in some particular spatial relation with the object on which it is desired to produce an effect ? Having learned that causes and effects are spatially contiguous, or having acquired that aspect of the concept of cause, the child suddenly finds standard conditioning situations puzzling, difficult and indeed aversive. This can lead to paradoxes in the results of studies of learning. It can seem that as a child becomes older he becomes less efficient in learning situations. He becomes less efficient because he has a new concept, a concept that changes the way he interprets events in the world around him. Looked at strictly in terms of performance, this is a detrimental change. Nonetheless this small change in the child's concept of causality does not simply add something to his corpus of knowledge. It actually radically and drastically changes the way in which he interprets the world.

We must presume from the kind of conditioning data I mentioned above that the baby prior to nine or ten months has a very magical view of the world. Any event that follows an act of his will be seen

by him as causally connected to his act. His world must be magical indeed, full of strange cause/effect sequences which suddenly become inoperative. After the concept of cause has been refined to include the notion of spatial contiguity, this magically causal world suddenly disappears and the child is literally living in a different environment, an environment in which causal concepts have a completely different meaning.

Similar very broad changes obviously also occur when the child of seven or eight changes to the stage of concrete operations. The changes that take place during this stage of development are enormous. One aspect of the changes seems to me particularly drastic. It is the change from reliance on immediate sensory input to a willingness to distrust the concurrent input through the senses in comprehending events. This is clearly brought out in an experiment of Piaget's on the horizontal/vertical illusion (Piaget, 1961). The horizontal/vertical illusion effectively grows with age so that older children are more subject to the illusion than are younger children. Nonetheless the illusion is completely overcome in older children if they are shown that the two sticks used for the illusion are in fact the same length. If, after they have been shown this, the sticks are then rotated to make a horizontal/vertical illusion, they will maintain that they are the same length although they look different. Younger children by contrast will say that the sticks are no longer of the same length, that one of them has grown. This queer separation of appearance from reality will obviously change the way the child interprets events in the world around him.

The idea that there is a reality that may be different from appearance is of enormous significance in the life of the child. The environment of a child who has made this distinction will under no circumstances be the same as the environment of a child who has not yet attained such a distinction. Similar and perhaps more profound changes accompany the transition to the stage of formal operations. The child in the formal operations stage no longer thinks simply in terms of appearance and reality but wishes to explain appearance and reality in terms of hypothetical entities. The twelve year old has begun to construct a version of the atomic hypothesis. The advances in comprehension possible using such an hypothesis to interpret data are obvious. However there are quite clear detrimental effects as well. It seems likely that a simple concrete concept such as conservation of weight is lost, at least temporarily, but perhaps permanently, as a result of the emergence of the atomic hypothesis in the mind of the child. This is a topic we shall return to below when we are considering repetition in development.

The point I particularly wish to make here is that the sequences described by Piaget are completely incompatible with a growth model of

development. A child who has moved from one Piagetian stage to the next does not retain all of the information, knowledge etc. that he had at the prior stage. Much of it is discarded necessarily; even information or strategies that are useful will be discarded if they are incompatible with the prevailing concepts of the new stage. The child who has advanced one stage is not simply one stage bigger - he is a completely different child. Furthermore, that child has a completely different environment. Events in the world have completely different meanings for him as his conceptual structure for these events changes.

The phenomena of repetition in development provide the most direct challenge to the growth model of psychological development. That challenge was first formulated by Piaget with his concept of vertical décalage. The Piagetian concept is a descriptive concept. It alludes to the seemingly very odd fact that a child may have to master a concept several times if different response systems are involved in the expression of the concept. The baby masters many things in his behaviour that he cannot express in words for many years thereafter. The descriptive concept itself is interesting enough. It gave rise to one of the slogans of the educational revolution of the late 1950s - the slogan that any subject can be taught to any child of any age in some form. This was an expression of the fact that a child, a baby even, can learn to play games which involve fairly abstract concepts which he will not be able to formulate verbally for many years afterwards. The implicit assumption underlying the slogan was that this early practice in using these concepts would facilitate their later expression in verbal terms.

The descriptive concept of décalage does not directly challenge the growth model of development. However, a closer analysis of the phenomenon produces data that are directly challenging. Consider one concept where vertical décalage does occur. I refer to the development of the conservation of weight. Mounoud and I studied the development of a non-verbal form of weight conservation (Mounoud and Bower, 1974). Our response measures were force of grasp and arm movement. What we found, in essence, was that the one year old child tends to equate weight with length, so the longer an object is the heavier he thinks it will be. Thus if we take a child of this age and give him a ball of plasticine to pick up and manipulate he will rapidly learn the weight of that particular ball. If we transform the ball so as to elongate it and then give it to the child again, the child watching all the while, the child will think that the plasticine has become heavier and will make an appropriate error, his arm flying up over his head. Conversely, if we take a sausage shape, familiarise the child with that, roll it up into a ball and then give it to him again, he will think it has become lighter and will make a typical error,

the arm dropping. The eighteen month old child by contrast will not make these mistakes. While he still tends to equate weight with length when dealing with unfamiliar objects, he knows that an object stays the same under changes in shape, that weight is invariant under shape transformation. Thus, if you familiarise him with a ball and then transform the ball into a sausage, with him watching, the eighteen month old will make no mistakes at all. If we do the converse, sausage to ball, again the child will make no mistakes whatsoever. The child has acquired a concept of conservation of weight; a knowledge that weight is invariant under shape transformation. He can only express this concept in behaviour.

It will be many years - five or six - before the same concept can be expressed in words; but what happens to the weight concept as the child begins to express himself verbally ? By eighteen months he knows in some fashion that weight is invariant under shape transformation. If we ask an older child, a three - or four - year old, to tell us whether weight is invariant under shape transformation, by showing him a ball transformed into a sausage, for example, he betrays no such knowledge. He will say that the sausage is heavier than the ball because it is longer. There is nothing here really incompatible with a growth model of development. What is incompatible is that with the appearance of verbal error, the behavioural error again occurs. The child given the same non-verbal task that he could pass at one and a half years of age will fail and make the errors typical of a one year old in this manipulation of transformed objects (Sheeran, 1972, Sheeran and Bower, 1976). A skill that has been in the child's repertoire since the age of one and a half will typically disappear around the age of three and a half, when the child starts to think about weight in verbal terms or with the use of words. For reasons that are not completely clear, although they obviously have to do with increasing use of language, the child loses a skill, a concept that he had and kept for two years.

Similar detrimental changes occur with size judgements and number judgements (Bever and Mehler, 1968; Maratsos, 1974). Of course when the child formulates a verbal concept of conservation of weight then his behavioural concept recovers as well at the same time. However, the story of development of weight conservation is not over at this time because there is a third loss of weight conservation. Weight conservation, expressed both verbally and in behaviour, disappears at around eleven or twelve, concurrent with the step into formal operations. Dasen, the first to describe this loss, speculated that the teenager is beginning to formulate concepts of density - ways of understanding how weight and volume can vary independently (Dasen, 1975). Once the relations between weight, volume and density are formulated, the developing child has a more powerful way of coping

with phenomena in the world. However, in the interim period the ability to conserve weight is gone. Potentially more important is the discovery that there are cultures in which no recovery is made, cultures in which adults are incapable of any of the standard conservations, although children in the same culture are. It seems that the step forward towards formal operations may result in a permanent loss of ability.

The data on repetition indicate that conceptual abilities will wax, wane, wax again, wane again and possibly wax again. Development is thus not a unidimensional, monotonic process of growth. There are successive reorganisations; in the course of these, the child may lose competences which he clearly had before. Since the essence of the growth model is the assertion that development is inclusive and incremental in a continuous way, it is obviously incompatible with such data. There are enough such data around for us seriously to question the growth model.

One of the worst features of the growth model from my point of view is that it takes no account of cultural diversity. Even in terms of the Piagetian stages it is quite common to see various cultural groups, who do not end up with the same set of formal concepts as we do, being described as inferior in some way or equivalent only to the younger Western-European child. Connotation of inferiority follows from the idea that intelligence is something uni-dimensional along which all individuals progress to some more or less pre-determined limit. Few anthropologists would accept this implication of inferiority, for anthropologists, far more than psychologists, believe that manifested intelligence is a matter of the cultural milieu an individual grows in. Implication of inferiority is hard to avoid if we stick with the simple growth model of development I outlined in the beginning.

Is there an alternative model of development that retains the virtues of the growth model and nonetheless can cope with the kind of data I have been describing ? Obviously I think there is, or I would not have begun on this paper. Just as the growth model of psychological development is based on an analogy with physical growth so I would like to base my alternative theory, not on the idea of physical growth, but on the related phenomenon of differentiation.

Organisms do not simply grow; they also differentiate. Processes of differentiation have recently been greatly elucidated by advances in molecular biology. The factors producing differentiation are not as yet clearly understood but at least the basic problems are. The basic problem stems from the fact that every cell in our body - brain cell, eye, hair, liver, teeth, fingernails - is, in terms of its genetic nucleus, exactly the same. This point was dramatically demonstrated by the experiments of Gurdon, who took the nucleus from a liver cell of an adult frog and implanted it in an ennucleated ovum.

The resultant clone grew to make an adult frog. Any cell can turn into a brain cell, a liver cell, a hair cell. The difference between these cells, and they are obviously very different, is not a matter of genetic difference. It is a matter of locus in the environment. The parameters of this process were described by classical embryologists. It is known that if at an early stage in development pieces of tissue are taken from one part of the embryo and transplanted to another part of the embryo, they will develop in accordance with their new location. After enough developmental time has gone by, after the organism has reached a sufficient state of differentiation, this is impossible. The tissue is then said to be determined. If transplanted to a new location, it will grow with the characteristics of its former location. There are thus limits on the plasticity of development which seem to be determined by duration of development in a particular environment. Past a particular time period the original plasticity is lost.

The second problem is that it is very hard to prevent some differentiation from taking place. Even cells kept in medium will lose their capacity to develop in any possible way. Within an intact organism the process is just that much more immutable. Differentiation will take place. Determination will take place. The kind of determination and differentiation that occurs is a function of the locus of the cell in the overall environment made up of the developing body and its environment. However, in no sense does liver develop because the cells that make up liver have a genetic predisposition to become liver cells. The same cells in a different place might become brain cells. The determination of differentiation is entirely an environmental matter. All the cells in the body are equipotential.

The genetic processes that determine the differentiation of cells into the complex structure that makes up intact functioning organisms are surely akin to the genetic processes that determine the differentiation and specialisation of areas of the brain. They are therefore likely to be akin to the processes that determine the differentiation and specification of behaviour. Behaviour does depend on the brain and the brain is a differentiating organ just like every other organ in the body. The difference is, though, that the environment of the brain is not simply a geographical, physical-chemical environment. It is also a psychological environment. The subject matter of psychology in large part makes up the environment for the brain. Various inputs from the psychological environment will play a role in determining the nature of differentiation within the brain. Seeing is a psychological event and we know that seeing or not seeing produces effects on the brain.

For a long time we have thought of these effects in terms of a growth model. We have simply thought that the unstimulated brain or

unstimulated part of a brain did not grow. It seems to me that there is an increasing body of evidence that this is not the case. It appears that, if the brain does not receive its normal inputs but still receives some other inputs, then these other inputs will take over more than their usual fair share of the brain. This seems to be true in the case of vision; if input to the eye is biased in such a way that only one part of the brain is stimulated, that part of the eye will come to take over more of the brain than it would normally have done. Similarly, if input is restricted to one eye, that one will take over cells which would normally respond to both eyes. If the input is biased so that the eye will only see horizontal stripes then horizontal stripes will take over cells which would normally be responsive to vertical stripes.

A recent study implies that the limitation on language learning which occurs when children have not been exposed to language for many years comes about also because the areas of the brain normally available for language functions are taken over by other functions. In the case of Genie, who is learning language at the late age of fourteen, one part of one hemisphere is apparently still available for language (Curtiss et al, 1974). Presumably if she had not begun to learn to speak, even that area of the brain would have been taken over for some other non-linguistic function. The growth hypothesis simply does not make sense of cases like this. We are not considering failure to grow along a single specified dimension. We are dealing with the re-direction and re-determination of processes of differentiation within the growing brain. The re-direction and re-determination are environmentally determined, but they do not result in a brain which is simply small. They result in one which is qualitatively different, which is organised for different purposes.

Is there any evidence that processes of re-direction similar to those described above occur for strictly psychological development ? I think that there is. The case of blindness provides the most obvious example. There have been many attempts to describe the handicap that blindness places on a developing child. Obviously, save under very special circumstances, the blind child can never ever have the three-dimensional input that the seeing child can have. What he does have are series of inputs that are organised in time. Time is a one-dimensional continuum as opposed to the three-dimensional framework of visual space. As is well-known, the developing blind child cannot cope with three-dimensional problems at all. His world is organised in time, as is shown by the experiments of Hermelin and O'Connor (1972), Hatwell (1966) and others. The ability to organise the world in temporal terms is obviously a direct consequence of the lack of three-dimensional input during the early months of life. A strange and puzzling fact is, though, that if the input is not given in the first

few months of life then the habit of dealing with the world in a one-dimensional way is fully and firmly established. It seems to be the case that it is not worth while restoring sight to a child over six months who has been blind from birth, because he will never acquire the habits or capacities that will allow him to use vision. He will never acquire the concepts that will allow him to understand geometry. Obviously no six-month-old can understand geometry but something has happened to the brain of the seeing six-month-old that will allow him to understand geometry eventually. Something has happened to the brain of the blind six-month-old which means he will never be able to understand geometry. It seems to me nonsense in this case to talk of growth. The blind child is not six months or any age behind the seeing child in terms of development. The blind child has developed off in a completely different direction, a direction that leads to coping with the world in terms of a single dimension, the dimension of time.

The important point that I am trying to make here by referring to studies of the blind is that development is directional rather than incremental. A child who has not had vision for the first six months and is then given vision, does not start off and stay six months behind the normal child. The child has begun on an entirely different developmental pathway and cannot transfer to the normal developmental pathway. By contrast, a child who has had vision through the first year of life and then goes blind has developed sufficiently far down the three-dimensional path that the loss of vision at that age is not enough to direct him away from it and on to a strictly temporal path. The famous mathematician Tolberson went blind at an early age but it did not stop him developing as a famous geometer, perfectly able to comprehend the world in three-dimensional terms. The average geometer has had a great deal of experience of the world, seeing it in three-dimensional terms; to be denied most of that experience should make a fantastic difference on a growth model. In fact it does not seem to do so.

Similar things happen with children who have been hearing for some time (Lenneberg, 1967). If hearing loss occurs, they are never at the disadvantage that congenitally deaf children are. They can still organise the world in temporal terms in the temporal frame of language. The difference between the deaf child and the hearing child is thus not a matter of growth. It is a matter of direction, a matter of differentiation. The growing brain of the one has differentiated in one particular way. The growing brain of the other has differentiated in a different way. Once these differentiations have gone far enough they are determined and the brain cannot be re-shaped.

Does such an analysis help us comprehend any of the problems of normal development ? I think that it does. Consider the cyclic or repetitive processes we discussed earlier. There is an obvious temptation to say that the concepts manifested at each of the stages

of development are independent of all the others. While this is a tempting line of argument, and one which many distinguished psychologists have taken, I think it is one we must discard. If we do not, we have no way to make sense of the data on the development of the blind. The blind people simply do not develop three-dimensional concepts. The critical period for developing these concepts is during the first phase of acquisition, the phase of infancy. Concepts gained during infancy by the normal child will be lost during the assault of language. The blind child will gain language but he will never gain the spatial concepts expressed in behaviour and in words which the sighted child will develop. We know from studies on the restoration of sight that successful development during the second phase is dependent on successful development during the first phase. In some way, the acquisitions of the first phase, though lost, programme or determine the acquisitions of the later phases. This is not an embryologically unfamiliar idea for we do know that differentiated tissue will induce differentiation in neighbouring undifferentiated tissue. In the case of the brain it seems possible that organisation of one area will determine processes of organisation in those areas with which it connects; that there will be some consonance between the organisation of the first and the later differentiating parts of the brain.

In more psychological terms too, it seems quite plausible that the initial inputs to the brain establish a framework wherein all successive inputs will be organised, so that the child who has acquired in infancy three-dimensional concepts forever after copes with the world or sees the world through a pair of three-dimensional spectacles. All subsequent inputs are referred to this very basic, very primordial frame. If this were the case, then what is lost during the declining phases of development would not be the basic framework but some specific derivatives from it. There is some evidence in favour of this hypothesis from studies showing that if a child is presented with second phase problems at a stage when he has not elaborated very specific solutions to the first stage problems, he may paradoxically transfer with perfect fluency.

The most direct evidence to this point comes from a study of the development of the comprehension of spatial relations in infancy (di Schönen, 1974; Wishart and Bower, 1975; Brown and Bower, 1976). Babies typically do not understand that two objects can be in spatial contact 'on', 'in', 'behind' or 'in front of' one another. Tasks like those shown in Figure 5 are difficult for babies throughout the first year of life. The tasks shown in Figure 5 all involve the use of the hands. The same difficulties crop up if one looks at eye movements as behaviour indicators (Figure 6). One can practise the tasks shown in Figure 6 at an earlier age than one can practise the manual tasks shown in Figure 5.

If babies are given practice on these eye tracking tasks, then they show accelerated success in coping with both types of task. However, it is not the case that the more eye tracking practice that is given, the more acceleration there will be in the manual retrieval tasks. The babies seem to learn initially that an object can be 'on', 'in', 'behind' another object and still exist as a separate object. If transferred at this point to the manual retrieval tasks, the babies perform perfectly. If given practice beyond this point, the babies learn a more efficient tracking strategy which is much more specific to the tracking situation than is the initial discovery. For example, they learn to cope with the 'behind' situation in terms of a rule like "when an object moving from left to right disappears at the left edge of a screen, look for it at the right edge of the screen after x seconds". This is a very successful rule in the tracking situation but obviously of no use in the manual situation. The baby, who has relied on this rule for success in situations with screens, etc., has to learn to give it up and go back to the more basic rule. During this time, the baby is not successful on the manual task and will become less successful on the tracking task, in fact. However, the attainment of the basic item of knowledge still ensures an eventual acceleration of development.

A similar phenomenon may be behind the decline in verbal conservation demonstrated by Bever and Mehler and others and in the decline of accurate size measurements found by Maratsos. In these cross-sectional studies it was found that younger children, i.e., two and three year old, were more likely to give correct verbal responses in number conservation or size judgements situations than were older children. Young children would not normally be presented with such tasks, nor would they have had much experience in the behavioural equivalents of these verbal tasks. It thus seems possible that the reason for their comparatively more successful behaviour was that they were able to refer the new problem to an existing framework which had not yet become very specific. This speculation would have to be checked out with longitudinal studies; it does not seem implausible. This may at least give us an outline of why development at later ages depends on prior successful development at earlier ages, without development in fact being continuous and incremental. If we are talking about specifications or frameworks we are not committed to the kind of analysis that a growth model of development demands.

What of the issue of compensatory education ? Is there anything in this analysis that would illumine the problems of compensatory education ? I think if we go to the extreme case of the blind child we may perhaps understand some of the problems involved in compensatory education. If development is a matter of choosing a developmental path which is then relatively fixed, or a matter of selecting a framework

which will constrain the interpretation of all future events, I think we can see that the problem of compensatory education for the blind is in fact very difficult. If we expose a blind child to problems and problem situations that require the use of a three-dimensional framework, the child will not be able to cope with these, except by elaborating his own one-dimensional framework. Sooner or later, though, the one-dimensional framework will crack and all that can happen, all that will happen, will be that the child will quit the situation. Instead of advancing in knowledge through compensatory education, the child might withdraw into apathetic incomprehension in the face of the problems posed by the three-dimensional world to an organism with a one-dimensional mind. There is some evidence of this (Hatwell, 1966).

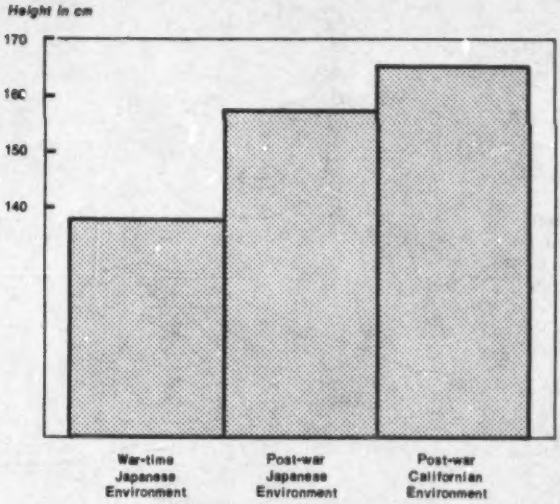
Cross-cultural studies indicate that the critical period for establishing a basic framework for other mathematical or scientific concepts is much lengthier than it is in the case of spatial framework. Nonetheless there are critical periods. Children in given cultures can acquire concepts that adults in the same cultures cannot (Dasen, 1975; Sankoff and Laberge, 1973).

The idea of early frameworks specifying the possible paths in later development need not be restricted to cognitive development. It is highly likely that the attitudes to life and the world that make learning possible are similarly determined early in life. Bateson suggested many years ago that the child's initial learning experiences determine basic attitudes or frames which will determine what kinds of learning will be possible later (Bateson, 1942). Thus in Western middle class society the child is early on encouraged to be instrumental and active in seeking knowledge for himself. In other cultures, this basic frame is discouraged; children may instead be taught to accept authority, unquestioningly. It appears that some sub-cultures within Western society share this basic attitude. Surely it is obvious that if a child has learned to accept authority and not to search for knowledge, he will not acquire knowledge if placed in a rich environment permitting acquisition but not instilling it. If the skills are fed in by authority figures, however, such children might learn very well to perform the skills necessary for success in Western society. This may well be why Bereiter and his associates are successful with ghetto children, using authoritative techniques of instruction (Bereiter, 1972). He teaches the children within their accustomed frame, and does not try to force them into one they cannot use.

Basically I am arguing that any attempt at compensatory education must take account not of the level the child is at, but of the pathway the child is on. If two children are on different developmental pathways, viewing the world through different frames, they require very different treatments if their development is to be successful.

Unless compensatory education is to begin at birth, the different paths that have developed will require different treatments. The only alternative is to spend time and money finding out if it is possible to move children from one path to another, although I remain pessimistic about the chances of success in such a venture.

Figure 1



Range for height in Japanese children in three nutritional environments.

Figure 2

		Japanese Children	American Children	Japanese/ American Children
Height in cm	Boys	155	165	160
	Girls	150	160	155

Proportion of variance in height contributed by genetic factors alone among children living in California.

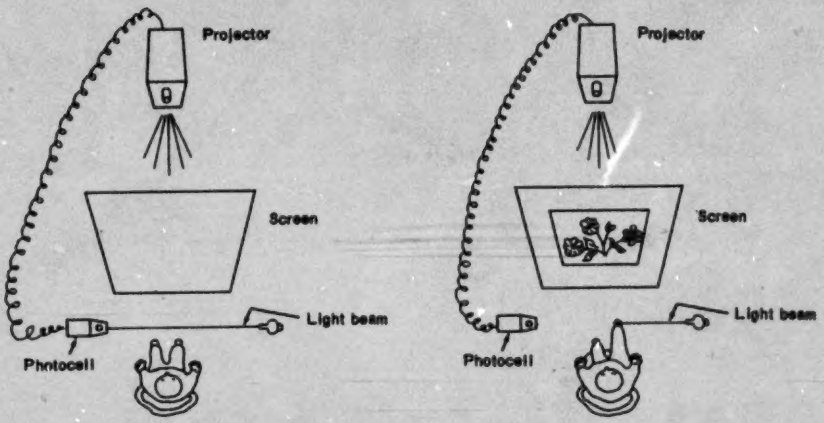
Figure 3A

Learning that cause and effect are spatially contiguous : the child pulls the cloth to get at the toy.

Figure 3B

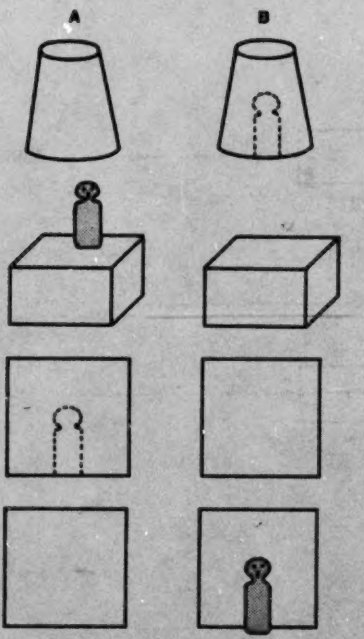
The child pulls the cloth again, but the toy is not on it - hence the disappointment.

Figure 4



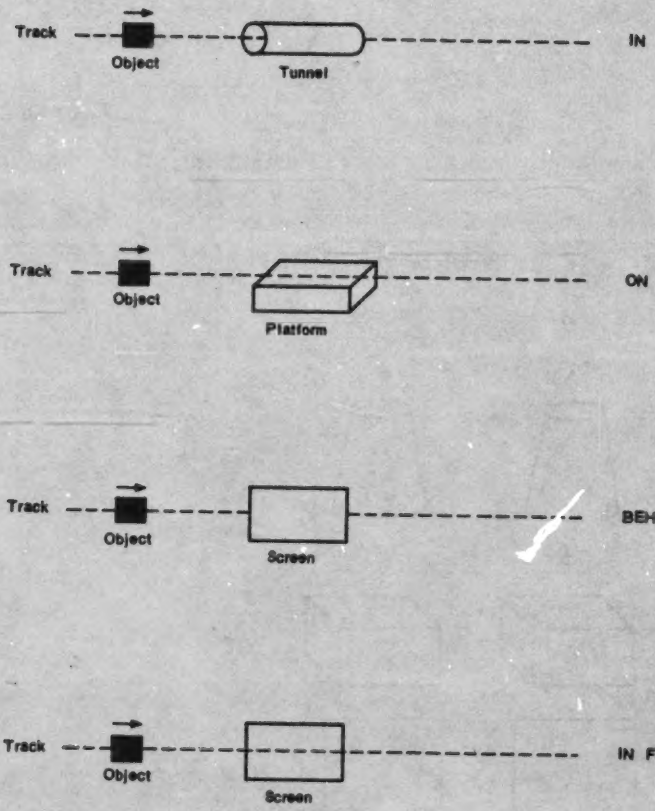
A standard conditioning situation (see text).

Figure 5



In the four tasks shown the baby is required to find the object. The task consists of two trials with the object being placed on, say, side A followed by a third trial where the object is placed on the other side B. Babies in the first year of life will typically continue to search for the object in the place where it has been in the two previous trials, although they quite clearly saw it being placed on the other side.

Figure 6



In these four tasks the baby indicates by his eye movements where he thinks the object is when it goes into the tunnel, onto the platform, behind the screen or in front of the screen. In all four cases, when the object is in a spatial relationship with another object, the baby acts as if it had disappeared.

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